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UNITED STATES DEPARTMENT OF AGRICULTURE WASHINGTON, D. C.

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INTRODUCTION

The investigations conducted by the Bureau of Entomology of the United States Department of Agriculture for the purpose of studying grape phylloxera, *Phylloxera vitifoliae* (Fitch), under California conditions, the results of which have been published (*2*),[2] disclosed a most interesting fact concerning the destruction of vines. In California the injury caused by phylloxera, though betokening serious consequences by the gradual stunting of vines, was very slow in its progress, requiring as many as 20 years for the destruction of some individual vineyards, compared to the rapid devastation which overtook the vineyards of France when 2,000,000 acres of vineyards were practically destroyed within a similar period.

These investigations also brought out very forcibly another phase of the insect's injury. Infestations were discovered to occur very

[1] The senior writer resigned from the Bureau of Entomology on September 1, 1918, to accept a position with the California State Department of Agriculture. Certain of the observations recorded in this report were made after he severed his connections with the bureau.

[2] Reference is made by *italic* numbers in parentheses to "Literature cited," p. 39.

commonly, accompanied most often by advanced stages of injury, on vines growing in certain types of soils; while these conditions rarely, or much less frequently, prevailed on other types of soil in the same vineyard district. This gave reason to presume that different types of soils favored or hindered the insect. The plausibility of this view is supported by the experience of French viticulturists of some years back which is expressed in an axiomatic rule pertaining to phylloxera control, that light-textured or sandy soils containing as much as 60 per cent of silicate sand foster immunity to phylloxera.

The control of phylloxera by the use of resistant roots is to date the only known practical method; at best it is costly, and in its application not so reliable as might be desired when it comes to selecting a variety suitable to soil and congenial to scion. If certain types or groups of soils in California possess an attribute which opposes phylloxera propagation, like that of soils in Europe containing 60 per cent silicate sand, though not necessarily insuring immunity, a certain degree of control of phylloxera might be achieved by planting vineyards on such types of soil.

With this possibility in view, the Bureau of Entomology, in collaboration with the Bureau of Soils, undertook a survey of the vineyard districts of California to determine a relationship between phylloxera infestation and various types of soils.

HISTORY OF THE INVESTIGATION

This survey was begun in 1915 as a preliminary investigation, continued during the following years, and completed in 1920, when the detailed survey of Fresno County was extended into Tulare County. At first this work consisted in making a general study of the relations of phylloxera infestation to types of soil, such as hardpan soils, well-drained soils, soils water saturated during certain seasons and lacking moisture the balance of the year, and saline or alkali soils in which vines manifest by a dwarfed growth a pseudoinfestation.

While the writers were traveling over the State in carrying out this preliminary work, they hoped that discovery would be made of a grape-growing area or vineyard district corresponding, if possible, to a hypothetical vineyard district offering appropriate conditions of phylloxera infestation and embodying most of the important types of California soils suitable for grape growing, such as indicated below:

Hypothetical vineyard district

Grapes	1. An extensive area of vineyards. 2. Only a few varieties of grapes (many would complicate investigations).
Phylloxera	1. Infestations of long standing to insure adequate dissemination. 2. Centers of infestations numerous and well distributed.
Soils	1. Most of the soil types favorable for grape culture. 2. Areas planted to the same variety of grapes and offering a contrast of types of soils.

The counties of Napa and Sonoma were first visited for the reason that they were counties where phylloxera infestation dated back 30

or more years and where vineyards had suffered more than in other parts of the State.

San Joaquin was the next county visited because of its variety of soils planted to grapes. These comprised only a few types but types that were very distinct in character. They included the heavy black clay adobe and clay loam soils of the Stockton series, the deep friable sandy loam soils of the Hanford series, and the compact hardpan soils of the Madera and San Joaquin series embracing the sandy loam, fine sandy loam, loam, and clay loam types.

By the time these three counties had been carefully investigated, frequency of infestation and more or less advanced stages of injury on certain types of soil were beginning to indicate a sustained correlation. In 1918 the work was transferred to Fresno County, somewhat sooner, however, than the general plan which had been mapped out indicated, at the request of F. P. Roullard, horticultural commissioner of Fresno County, who was desirous of ascertaining, in general, the extent of phylloxera infestation in the Fresno vineyards. He contributed much valuable assistance to this work in his official capacity and through his personal knowledge of abnormal conditions relative to vines in different localities of his county.

Later the general infestation was traced into Tulare County, and the investigation was carried on by request of the horticultural commissioner, Charles F. Collins, whose office rendered valuable assistance.

Fresno County proved to be an appropriate field wherein conditions in many respects corresponded to those of the hypothetical vineyard district already mentioned. Phylloxera infestation had existed in the county for from 20 to 30 years. During this time little or no attempt had been made by the grape growers to arrest the dissemination of the insect, which therefore had ample opportunity to spread in every natural and accidental way, from new as well as from originally infested centers, to vines growing in different types of soils. Thus this county presented conditions most favorable for the observation and study of the relationship of soils to the dissemination and injury of the insect.

At first considerable time was devoted to determining whether or not phylloxera infestation alone caused the stunting of vines observed in certain localities. It was discovered that water saturation of soil, often with nematode infestation present and likewise excess of mineral salts in the soil, has an effect upon grapevines somewhat similar to phylloxera injury, inasmuch as the roots are injured and the vine correspondingly weakened. The shoots lack vigor, and the canes remain dwarfed, giving to the vine a stunted, bushlike appearance. When conditions such as these are caused by phylloxera the vine assumes a characteristic shape designated as "cabbage head." With some experience it is possible to distinguish this stunted form of vines due to phylloxera infestation from the dwarfed shape of those suffering from other causes.

A separate section of this report is devoted to a discussion of these different stunted aspects of vines and how they may be distinguished. This subject is discussed at length and its importance emphasized for the reason that once the writers had familiarized themselves with the distinctive features of the more commonly grown varieties of grapes, muscats, Sultanina (Thompson Seedless), Emperor, and Mal-

aga, a good portion of the survey made in Fresno County and later in Tulare County was conducted without the inspection of roots to ascertain the actual presence of the insect, unless the characteristic phylloxera spot in the vineyard and the telltale distinctive stunted shape of the vine were such as to create some misgivings as to the reliability of this method.

METHOD EMPLOYED IN MAKING THE SURVEY

The method employed was the same in all cases; however, in Fresno County the investigations were confined to smaller areas of vineyard. The ground was gone over in an automobile at a very moderate speed. The field party consisted of an entomologist, a soil expert, a driver, and usually the county horticultural commissioner or his deputy.

All roads traversing the vineyard districts were driven over, first those oriented north and south; afterward those east and west. The vineyard districts were thus divided into a checkerboard pattern of rectangular areas, either 1 mile square, one-half mile square, or 1 mile by one-half mile, according to the distance between the roads, some of the areas thus segregated being as small as a quarter section.

During the drives, vineyards on each side of the road were scrutinized to detect affected vines and phylloxera spots. When these were found and recognized to be of phylloxera origin, their location was correspondingly marked with a dot on a soil-survey map of the Bureau of Soils, which was used as a guide; and these dots, when considered collectively, furnished data for outlining infested areas. The frequency with which phylloxera infestation occurred in certain types of soil, and the degree of infestation most often evidenced by the dwarfed conditions of the vines, furnished the factors for determining relationship of phylloxera infestation to different types of soil.

The approximate boundaries of the vineyard districts within the counties were thus outlined and are indicated upon the accompanying map. Phylloxera examinations and soil examinations and borings were made at frequent intervals in localities in which the appearance of the vines was such as to indicate phylloxera infestation or some other disturbing factor or unfavorable condition. A large proportion of the examinations indicated that unfavorable conditions of growth were due to causes other than phylloxera, whereas in others infestation was indicated by the characteristic dwarfed growth and other symptoms. Positive identification of the insect was not made in all cases, but only where doubt existed. The insect was, however, identified with sufficient frequency to establish an apparently consistent relationship to soil types. In most cases soil borings were made to an auger depth of 5½ feet, except where prevented by hardpan or other impenetrable materials. In Fresno County 145 borings were made, in addition to numerous surficial soil examinations. Many of these were accompanied by excavation about the base of the vines and a minute examination of the roots for evidence of the insect. The results of such examinations have rendered possible the outlining upon the map of the identified areas of general or widespread and local infestations.

The delineation of the phylloxerated areas upon this map must not be construed as indicating positive lines of demarkation between areas infested and those that are not. If this had been the intent, it is certain a much greater area would have been involved and outlined. Moreover, it would be an almost impossible task for the reason that vines which become infested after their root system is well established, for instance vines 10 to 14 years old, may withstand the insect's attack for some time, two to five years according to soil, climate, and variety of grape, before showing signs of perceptible dwarfing. Because of this fact, vineyards with infestations of several years standing were the only ones which were considered and which in fact could furnish the desired data for this survey.

For the purpose of comparative study, the principal groups of soils of the vineyard districts of Fresno and Tulare Counties have also been plotted and outlined upon the map to indicate graphically the types of soils and their relationship to phylloxera propagation.

CHARACTERISTIC GROWTH OF GRAPEVINES INDICATING PHYLLOXERA INJURY

Reliable indications other than the actual presence of phylloxera on the roots of the grapevine can be made use of for identifying phylloxera infestation of a more or less advanced stage. This does not apply to young vines and to early stages of the insect's attack.

Characteristic growth is a diagnostic feature of phylloxera infestation, which weakens the vine by destroying the function of the roots. This weakness is manifested by the vine through reduced length of the cane, shorter internodes, absence of active growing tips[3] of herbaceous shoots in the spring and also of tendrils throughout the growing season, provided lack of moisture in the soil, hot scorching winds, or other abnormal conditions are not responsible for such a state of the vine's growth. The color of the leaves is as dark a green as that of the nonaffected vines, though the dropping of the leaves may be slightly premature, and for this reason the autumnal discoloration of the leaves may occur somewhat earlier. These are the main indications from plant growth by which phylloxera infestation can be recognized; they are all the more significant when corroborated by spots of a peculiar character ("oil spots") in vineyards affected with phylloxera.

An infestation in a vineyard ordinarily begins with one vine, or a group of two or three, rarely more, to the roots of which phylloxerae have gained access. They form the starting point for a new center of infestation, from which diffusion of the insect follows. The spread progresses circularly from the center; the circles of affected rows of vines increase in the same way as a drop of oil spreads on water. This similarity has suggested the term "oil spot" to designate a phylloxera-infested area. At first one or two vines appear less vigorous than their neighbors. This condition is manifested by abnormally shortened canes and at times premature dropping of leaves, not necessarily preceded by yellow discoloration. The following year the lack of vigor is more noticeable, and the stunting becomes more

[3] See fig. 6, which shows a contrast of growth and appearance of herbaceous shoots of a healthy vine and vines suffering from phylloxera injury.

accentuated with time until these vines put forth a very short and scant growth and may even die. The crop diminishes in a corresponding manner. When the vines are much stunted they still continue to bear a few small, worthless bunches. While this is happening to the original vines, others surrounding them become similarly affected. Later other vines in rows farther away show the same symptoms.

After several years, when the vines first infested are about dead, vines at a distance of several rows each way show signs of reduced vigor. By this time the affected area in the vineyard is a well-defined spot with the vines most stunted or even dead at or near the center. This phylloxerated or "oil-spot" area is quite characteristic. (Fig. 1 and Pl. 1.) The spot is not always geometrically circular; it may be slightly oval, or the vines most affected may not be quite centrally located. Different causes modify the form of the spot. For instance, more vines may be affected from the center of infestation in the direction of prevailing winds, the wind having carried migrating larvae with it to the nearest vines; the spot may be elongated in the direction of the flow of rain or irrigation waters, which sometimes disseminate larvae; but in most cases the "oil-spot" form is recognizable, with a fairly well-defined center of long-standing infestation. More than one spot or less remote infestations may exist in a vineyard. In time these become confluent, but the old centers are often still discernible.

When the survey of Fresno County was begun, weak vines with stunted canes, of much the same aspect as phylloxerated vines, were frequently found in spotlike areas in vineyards in certain localities of the county. Much time was devoted to determining the cause of the stunting and in proving beyond doubt that phylloxera was in no way responsible for their abnormal behavior and peculiar aspect. In connection with many borings in places where vines were stunted but no phylloxera was found, it was noted that although the soil was more or less sandy it was saturated with water at a depth of 1 to 5 feet, and where there was no excess of water, evidence of the nature of the soil and other conditions pointed to a saturation at some seasonal period, probably at a time when irrigation of vineyards is usually practiced, and nematodes are very commonly present.

A careful study of soil conditions in conjunction with the peculiar stunted growth of the vines, corroborated by the conditions of the roots, has furnished the necessary factors to determine with accuracy whether the vines are phylloxera infested or suffering from soil and other conditions.

The characteristic dwarfed growth and peculiar deportment of phylloxera-diseased vines are distinct and readily discernible from those of vines suffering from other entomological as well as pathological and physiological causes.

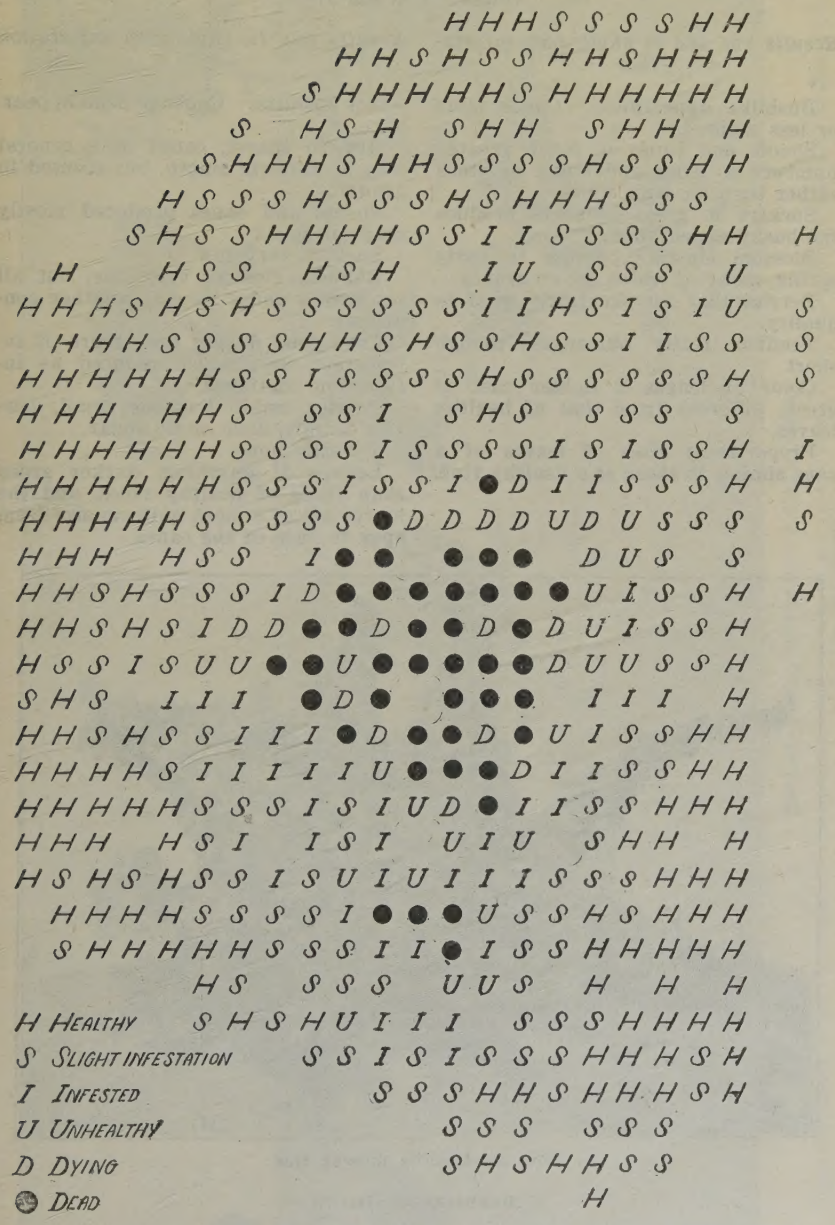

FIG. 1.—Phylloxera "spot" in Zinfandel vineyard, charted in 1914

DISTINGUISHING CHARACTERISTICS OF STUNTED VINES FOR THE SAME VARIETY

GROWTH OF VINES

(Figs. 2, 3, 4, and 5)

Results not due to phylloxera infestation	*Results due to phylloxera infestation*
Bushlike appearance. Canes more or less stunted.	Not bushlike. Cabbage-head appearance.
Shoots and canes in much greater numbers on arms and trunk of vines rather than on fruit spurs.	Growth sparse, canes in a general way of uniform length, but stunted in growth.
Suckers in great numbers produce the bushy appearance.	Shoots and canes produced mostly on fruit spurs.
Blossom clusters profuse in early spring, many of which set no grapes.	Suckers very few.
Berries that set are fairly good in quality.	Blossom clusters very few, but all set grapes under normal weather conditions.
Tendrils fairly numerous, though short.	Crop good during first years of infestation, very much reduced as infestation continues.
Color of leaves a lighter cast of green, different from that of healthy leaves.	Berries small, bunches small, berries contain little or no sugar.
Proportional sizes of leaves of a cane similar to those of a healthy vine.	Tendrils none.
	Leaves, if anything, darker green than those of healthy vines, and the leaves are of a more uniform size from apex to base of the canes.

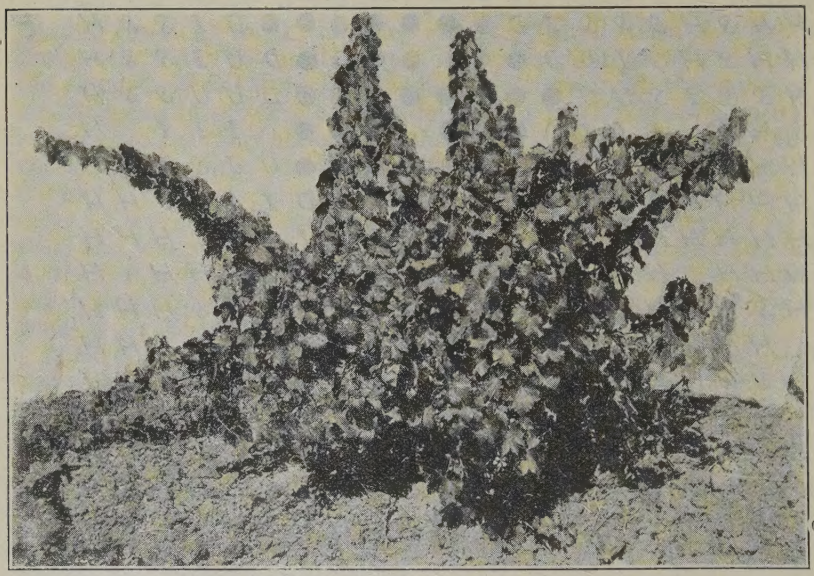

FIG. 2.—Healthy muscat vine

HERBACEOUS SHOOTS

(Fig. 6)

Results not due to phylloxera infestation	*Results due to phylloxera infestation*
In spring fairly vigorous, with rapidly growing tips of canes.	At no time vigorous growth and no rapidly growing tips.

AN OLD TOKAY VINEYARD IN CALIFORNIA

Phylloxera-infested "spot" in foreground; vine in central foreground to be rated 6; the two vines on sides in foreground to be rated 3 on scale of 1 to 10 of Phylloxera injury

ROOTS

Results not due to phylloxera infestation	*Results due to phylloxera infestation*
Often the epidermis and cortex of the under side of the roots in contact with the soil have rotted away. On the upper surface and sides the epidermis and cortex are normal, though very thin, smooth, and tight fitting. The phloem and xylem are often stained light pink to red in streaks. Nematodes are often present. The white fleshy feeders of the root develop in small, thick masses of rootlets quite characteristic. Mite *Rhizoglyphus elongatus* (Banks) rarely found on decayed cortex of roots caused by water saturation of the soil.	In the earlier stages of infestation phylloxerae are readily found on the roots.[4] In the advanced stage, phylloxerae have either abandoned the roots or are difficult to locate on them. However, the condition of the root usually gives some indication of the cause. All of the root, including epidermis, cortex, and cambium, is a sort of dry spongy mass resembling corky tissue before actual decay sets in. A species of mite, *R. elongatus* (Banks), of a white hyaline color with two brown spots on the dorsum of the abdomen, feeds upon the cortical tissues destroyed by the phylloxerae; the presence of this mite or of its abundant frass is a plausible indication of a recent phylloxera infestation, one that will be found in progress on better-preserved portions of the root system.

NATURE OF SOILS

Results not due to phylloxera infestation	*Results due to Phylloxera infestation*
Evidence of capillary water saturation during some seasonal epoch. Occurs in sand and very sandy loams. Nematode at times present.	No capillary water saturation, though soil may be water-soaked at times. Infestation does not occur in sands and very seldom in sandy loams unless these are plastic. Clay loams more susceptible to infestation, and clay soils much more susceptible.

SPOTS IN VINEYARD

Results not due to phylloxera infestation	*Results due to phylloxera infestation*
Spot conforms generally with topography of land. Has no characteristic shape. All vines of a spot are more or less uniformly stunted.	Spot seldom influenced by topography, except more prevalent in lower depressions of land. Vines of spot individually affected. Periphery of spot less stunted than center. Characteristic "oil spot."

[4] For detailed description of phylloxera injury to roots see The Grape Phylloxera in California (*2, p. 22–26*).

FIG. 3.—Stunted muscat vines, rated 3 on a scale of injury 1 to 10. A, Stunting due to grape phylloxera; B, stunting due to causes other than grape phylloxera, such as high water table, seasonal soil saturation, nematodes, etc.

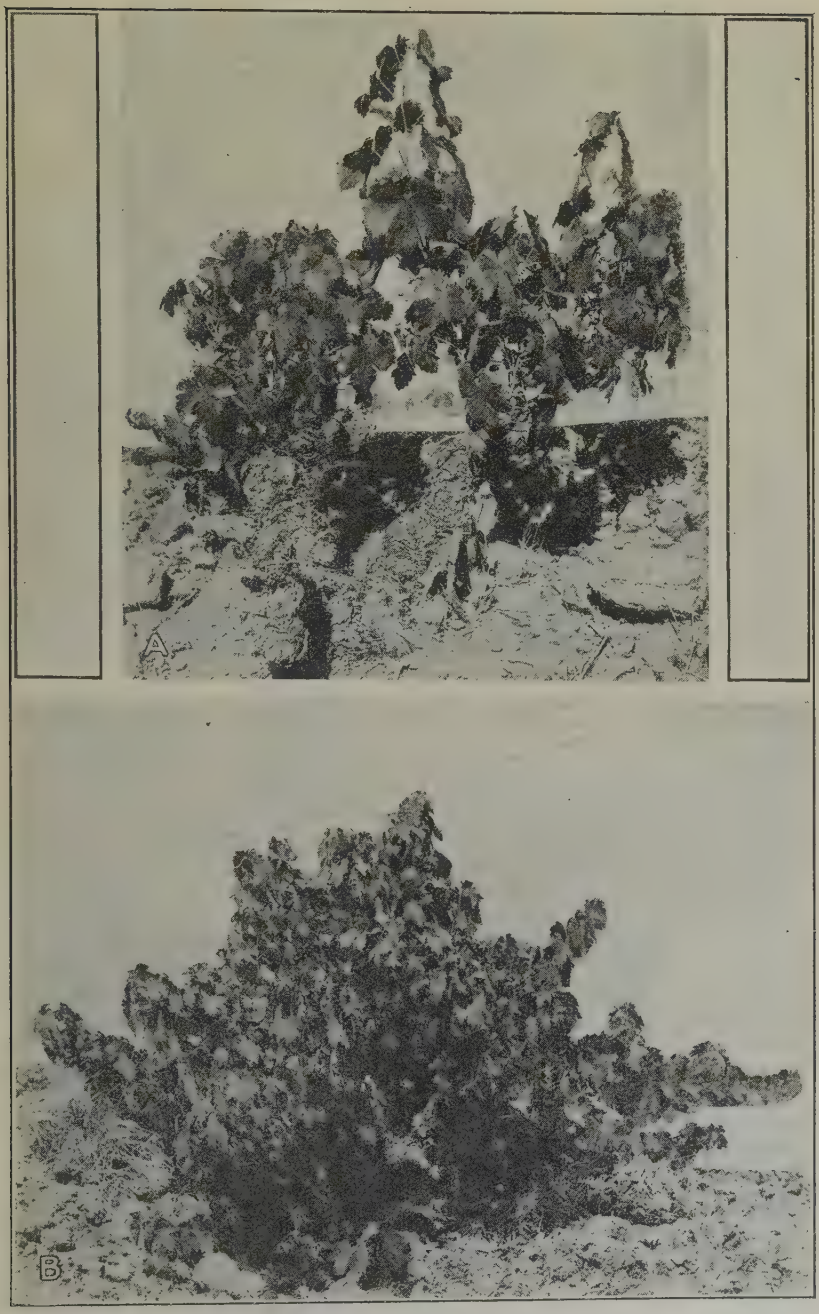

FIG. 4.—Stunted muscat vines, rated 5 on a scale of injury 1 to 10. A, Injury due to grape phylloxera; B, injury due to causes other than grape phylloxera, such as high water table, seasonal soil saturation, nematodes, etc.

FIG. 5.—Stunted muscat vines, rated 7 on a scale of injury 1 to 10. A, Injury due to grape phylloxera; B, injury due to causes other than grape phylloxera, such as high water table, seasonal soil saturation, nematodes, etc.

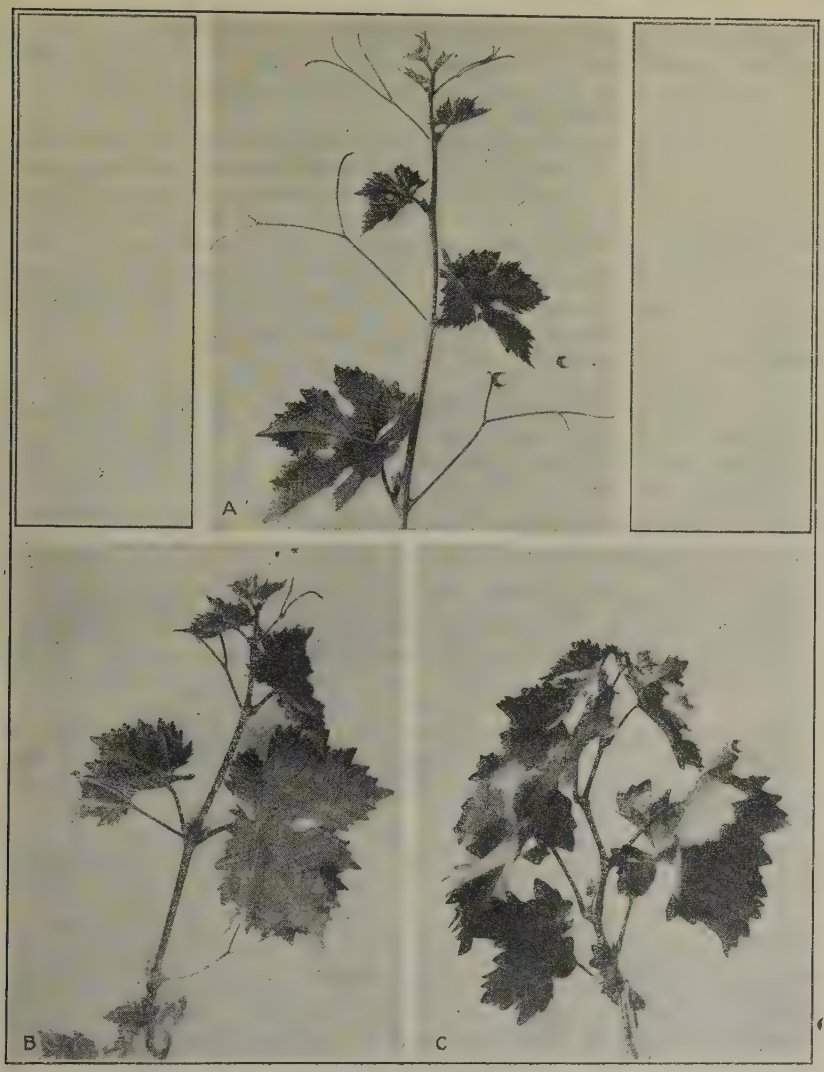

FIG. 6.—A, Muscat grapevine free from grape-phylloxera infestation, showing normal healthy growth of young shoots and tendrils; B, muscat grapevine showing symptoms of grape-phylloxera infestation in early stage; C, muscat grapevine showing symptoms of grape-phylloxera infestation in advanced stage

SANDY SOILS FOSTER IMMUNITY TO GRAPE PHYLLOXERA

EARLIER THEORIES AND INVESTIGATIONS

As far back as the late seventies, when a successful replanting of the vineyards in France was still problematical, a considerable acreage of sand dunes was planted to grapes on the shores of the Mediterranean Sea in the vicinity of Aiguesmortes. Prior to this enterprise and shortly after the phylloxera outbreak in France, it had been noticed that vines growing in sand were immune to the insect's attack. This suggested the planting of vineyards on soils as light in texture as beach sand. Vineyards were also planted on the sandy

waste lands of the ocean coast of Gascony (Landes de Gascogne), on the sandy coast lines of Tunis and Algeria, and on the alluvial sands of the valley of the River Rhone, which also apparently provided a like protection against phylloxera.

Why grapevines growing in sand are immune to phylloxera infestation is a question which has evoked many conjectures, and a number of theories have been advanced to explain the peculiar property in this respect inherent in sand.

The theories of Marion (*4*), Vannuccini (*8*), and Barral (*1*) stand out as the most plausible and accredited. Mayet (*5*), in his monograph on grape insects, gives a comprehensive and condensed statement of the principles underlying these theories. His summary, translated, is as follows:

> (1) A mechanical action of the sand particles, due to gravity, causing them to fill up all fissures as rapidly as they occur. These particles also oppose an impassable barrier to the migration of phylloxera and to their travel on the roots. The motion of the insect's legs crumbling down particles of sand thus obstructing its movements. This theory, the first to be promulgated, still has many partisans.
>
> (2) An insecticidal action, not definable, which can not be said to be chemical, but which, according to Professor Marion, is indubitable whatever the explanation may be.
>
> (3) A physical texture of the soil which enables all air which may be enclosed to be driven from it and permits water to thoroughly permeate it, whether its source be rain or water from the subsoil rising up through it by capillarity, killing the phylloxera by asphyxiation. This theory which is seemingly supported by very thorough experiments has been discussed at great lengths by Vannuccini, engineer, in a study published in 1888.

The experiments made by Marion (*4*) in support of his theory are interesting, and the results arrived at are convincing. He lays much stress upon the facility of displacement of grains and particles of sand.

Vannuccini (*8*) points out the porosity of sand as the main principle which fosters immunity. Mayet (*5*) quotes from Vannuccini as follows:

> In sand, air in the presence of water finds thousands of outlets by reason of the innumerable interstices existing between the grains or particles of sand, and should a bubble of air be submerged in water it would thus be enabled to rise up through the sand and gain the atmosphere. He offers as proof the following experiment: Let water be poured into one vessel containing sand and into another containing clay. As the water gradually sinks down through the sand air will bubble up through the water, whilst in the water covering the clay very few bubbles of air can be noticed rising up through the water, air remains imprisoned in the clay. Between these two extremes, sand and clay, there are types of soils of only part clay, easily permeated by water which retains only a few air bubbles.
>
> Thus only can different degrees of immunity be explained according to nature of soils. As proof, vines are immune when growing in pure sand but their resistance to infestation decreases in direct ratio to the increasing proportion of clay in the composition of the soil, to the extent that vines perish rapidly in heavy clay soils.

In his report to the Académie des Sciences, Barral (*1*) considers the subirrigation of the beach sands of Aiguesmortes the preeminent cause of immunity.

It is recognized as a fact that sandy soils foster immunity in direct ratio to the proportion of silicate sand which they contain. Sand of a different nature, as calcareous débris broken up into fine particles, is subject to more or less cementation and does not act

like silicate sand in obstructing phylloxera propagation. Soils containing 60 per cent of pure silicate sand are recognized as fostering immunity.

In this translation of parts of Mayet's work, the terms immunity and resistance have been used interchangeably as thought most suitable to convey the meaning implied, though the strict definition of immunity admits of no qualification, meaning absolute absence of or freedom from the insect, or in no way subject to its injury. Resistance does not imply so strict a limitation and may be qualified by different degrees of obstruction. However, as used in this bulletin, immunity indicates merely that difficulty is encountered by the phylloxera in living and propagating in the face of unfavorable conditions characteristic of certain soils. Resistance is possible only by virtue of the nature of the soil; it is a protection the vine acquires from the fact that it is not exposed, or only partially exposed, to the attack of the insect. This state of security is, so to speak, a pseudoresistance, in contradistinction to a resistance inherent in grape roots of certain species and varieties of American grapes.

Before passing to the study of the structural characteristics of the soils of California vineyards and their relation to immunity or resistance, in order to discuss conditions adverse to phylloxera life, prolificacy, and propagation, a brief review of the salient and pertinent features of the insect's biology will be helpful, whether considered from the objective or the subjective point of view.

HOW SAND SOILS AFFECT PHYLLOXERA

This problem should be viewed from two different angles in order to guide the discussions and deductions along certain lines and arrive at a solution. In this respect conditions affecting phylloxera life due to properties of soils are either adverse or favorable. The preponderance of either one of these conditions over the other will determine immunity, resistance, or disposition toward infestation.

Experiments made during a study of phylloxera under California conditions by the Bureau of Entomology (*2*, *p. 117–120*) have proved that phylloxera eggs hatch readily in water, either when floating or submerged in it; that the newly hatched larvae may live for over a week submerged or on the surface; and that these larvae are capable, at least after four days of exposure to water, to fix upon roots and develop in a regular manner.

The results of another experiment showed that one individual persisted over a month fixed on a root under water, and several other phylloxera larvae lived under water from 3 to 14 days.

Another experiment to test the resistance to water of hibernating larvae resulted as follows: Pieces of roots with the larvae on them were submerged in water during a six-week period, and 72 per cent of the phylloxera were destroyed. A five-week submersion caused a 63 per cent mortality, and in nine weeks all were destroyed.

Still another experiment showed that during a period of two months hibernating larvae withstood short intermittent submersions in water interrupted by periods of low temperature passing below 32° F.

Since eggs and larvae in contact with water act in the manner described, it is conceivable that irrigation and storm waters can aid

in their spread. Young larvae may be transported by surface flow for some distance, and in vineyards on porous soils may be carried downward into the soil; even subsurface seepage waters may aid in their dissemination. These experiments furnish definite evidence, and from it a clear idea is gained as to just how much the porosity of sand, and to varying lesser degrees that of sandy loams, clay loams, etc., may be credited with checking or obstructing phylloxera life. Two main phases of the phylloxera's life history influenced by soil conditions, namely, prolificacy and spread, must be taken into account in determining the cause of immunity and resistance.

FORMULATION OF THE THEORY

Capillarity and the motility of grains of sand, i. e., displacement by gravity or the crumbling of dry grains of sand, are the fundamental principles upon which the foregoing theories are based. These two physical soil characteristics alone, however, do not explain satisfactorily how conditions are brought about to obstruct phylloxera infestation to the extent of fostering immunity or even varying degrees of resistance for vines growing in certain types of soils.

Capillarity may cause destruction of phylloxera life due to water saturation of the soil, provided that saturation endures over a sufficiently long period. Intermittent saturation over periods of short duration, followed by periods during which good drainage conditions prevail, for instance, such as might be caused by rains, do a minimum of damage to the insect. This is proved by experiments on the resistance of phylloxera to water, as already noted.

The motific action of grains of sand is very effective against the development of phylloxera life at the surface of certain types of soil (more of this to be discussed later), but it becomes almost negligible as a destructive force in the substrata in which the roots of vines are located, since types of soils to become loose enough to crumble at such depths would either be saturated by water or drain dry and thus be worthless for growing grapes on a commercial basis.

Certain soils under given conditions have two other properties fully equal in importance to capillarity and the motific action of sand. They are the expansion and contraction caused, respectively, by moisture and desiccation.

Clay expands and increases in volume when moistened, and contracts or decreases in volume on drying. Sand neither expands with water nor contracts when drying. Sandy soils absorb water without increasing in volume and may have more or less moisture-retaining capacity, but they dry out with evaporation or drainage without any consequent decrease in volume.

These are the two peculiar attributes of soils which affect phylloxera in opposite ways; in clay textures most favorably and in sand textures most unfavorably. These attributes should be included with capillarity and motility of dry sand when a theory for immunity to phylloxera infestation for certain types of soils is formulated.

Sandy soils, or soils containing a high percentage of grit, whether of siliceous or of granitic origin, possess a high degree of capillarity, but, as before stated, are not susceptible to expansion upon becoming wet nor to contraction when drying out. The roots of vines grown under such conditions are constantly in close contact with the soil

particles, which compress them more as the roots grow in size. Under such conditions phylloxera can not circulate freely upon the roots. If by chance some phylloxera larvae should become established upon roots under such conditions, because of favorable cavities, they might develop normally for a time, but their movements would be greatly restricted when seeking to infest other parts of the roots. This is an instance in which phylloxera immunity, or at least a high degree of resistance, is fostered by the nature of the soils.

Clay soils possess very slow capillary action, but are subject to considerable expansion through absorption of moisture, and correspondingly are subject to contraction through loss of moisture. Roots of vines growing in soils of this character under wet conditions, such as during winter, are firmly impacted by reason of resulting expansion of the clay soil. Phylloxera at this time of the year are hibernants in a dormant state and consequently are not affected. As the moisture decreases, and resulting contraction follows, the soil in turn draws away from the roots, leaving a void or small vacant space next to the roots, into which air in due time penetrates. This condition is conducive to successful phylloxera propagation since it allows the unrestricted access of the phylloxera larvae to the entire root system in their search for more nutritious food when the roots that have been attacked decay and die. Clay soils check and crack upon experiencing loss of moisture, and the crevices which reach down to the roots facilitate the migration of larvae from the roots to the surface of the ground. Through similar crevices they find their way to roots of neighboring vines; thus the crevices facilitate the natural spread of the insect, not only in the same vineyard, but to other vineyards in a district. Clay soils, therefore, favor the propagation and natural spread of phylloxera. Only submersion of such soils for an extended period, or frequent excessive irrigations, may check the progress of the insect.

Soils containing varying proportions of clay and sand may or may not foster resistance to phylloxera infestation, depending upon the proportions of these constituents. Some may contain the requisite proportions of clay and sand to produce, through drying, a sufficient air space surrounding the roots while still retaining a favorable amount of moisture for active plant growth. And they may at the same time be of so friable a nature that when exposed to the drying effect of the atmosphere they will crumble into very loose fine-grained particles, forming a layer 1 or more inches thick on the surface of the ground, and filling any slight crevices which might exist. Under such conditions, if phylloxerae manage to gain access to the roots of a vine, they may be but little restricted in their propagation, but access to the surface of the ground and migration over it will be very seriously impeded. And if any phylloxera larvae should reach the surface of the ground by way of the roots and trunk, they would die from starvation and heat in their fruitless attempts to crawl over the mulch. The neighboring vines are thus rendered safe from attack or from extended phylloxera diffusion.

A vineyard established on soil types of a texture like that of Hanford sandy loam is quite safe against infestation due to casual

spread, such as when phylloxera are carried by wind, picking boxes, or in any other way by which the insect is deposited on the ground or even on the vine, since penetration of the soil to reach the roots is next to impossible because of the loose, pulverized surface mulch. Even when the roots are wet by rain or irrigation, the phylloxera have no chance to reach them because this loose surface becomes smoothly packed and remains so until evaporation takes place, when it rapidly crumbles again and becomes pulverized without artificial aid. In this case the immunity is due to the prevention of both natural and casual spread of the pest, but there would be no immunity to infestation if the insect happened to get in direct contact with the roots.

During this phylloxera survey an actual case of this kind was observed. A muscat vineyard of clay-loam texture had suffered from the attacks of phylloxera for a number of years and was so far depleted that it was finally dug up in the fall of 1917. Not knowing the cause of the death of the vineyard, the owner planted out a grape nursery on the same ground in the spring of 1918. The cuttings grew fairly well, although when dug up the following winter (1919), some of the vines had become infested. They were sold and shipped to another county and planted in a rich sandy loam well drained and well moistened by subirrigation. This type of soil is designated by the Bureau of Chemistry and Soils as the Hanford sandy loam. In the summer of 1920, after growing nearly two years in the vineyard, some of the vines, although showing infestation on the roots, had produced a fairly good growth and ordinarily would not have been suspected of harboring the insect had the vines not been traced from the original infested nursery.

This type of soil, the Hanford sandy loam, although rich and fertile, is very friable, and upon drying crumbles and soon becomes pulverized. If care is taken when planting to avoid casual infestation by seeing that the rooted vines are free from phylloxera when planted, this type of soil may be said to oppose infestation through natural spread. Although it does not foster immunity to infestation, it offers great advantages for the grape industry, inasmuch as vines growing in soils of this character are comparatively safe from attack of the insect.

SOILS OF THE VINEYARD DISTRICTS IN FRESNO AND TULARE COUNTIES AS RELATED TO PHYLLOXERA INFESTATION

Under this heading the predominating groups and types of soils occurring in this district are described, and their obvious relations to phylloxera infestation are discussed.

ORIGIN, FORMATION, AND CLASSIFICATION

The differentiation of the various soils, as indicated on the accompanying map, is based mainly upon previous detailed soil surveys made by the Bureau of Soils of the Fresno area, Calif., in 1912 (*7*), and the Porterville area, Calif., in 1908 (*6*), supplemented by a later reconnaissance survey of the middle portion of the San Joaquin Valley (*3*).

In the present survey slight revisions of the classification of the soils given in the previous surveys have been made in certain locali-

ties, and only groups of related soils similar in physical characteristics and in apparent relationship to phylloxera infestation are indicated upon the map accompanying this report.

The colored map (pl. 2) shows the relation of phylloxera infestation to types of soils at the time the survey was made. The map is not up-to-date with respect to the extent of phylloxera infestation. Also it is not a complete map of the two counties; only a few of the more prominent streams, railroads, highways, and towns are shown.

The soils of the district are derived predominantly from the older alluvial or sedimentary deposits of the valley. They are mainly of stream-laid origin and have their source in the varied rocks of the Sierra Nevada Mountains and foothills. These deposits have undergone more or less modification and weathering in place since their accumulation, with attendant changes in physical and mineralogical character through oxidation, hydration, and the breaking down of the mineral particles; leaching and deposition of lime, iron, and other minerals from solution; and infiltration and concentration of clay or the finer mineral particles in the subsoils. These processes are normally accompanied by the development of distinctive subsoils heavier in texture or more compact than the surface soils, and frequently by the formation of mineral or cemented nodules, concretions, and hardpans. Some of the included materials of light or sandy texture have, however, been modified or redistributed by winds, and the typical compact subsoils and hardpans are in many places deeply covered or undeveloped. The older materials also, through oxidation, tend to develop the more pronounced shades of brown or red color. These deposits occupy the older valley surfaces and are no longer being accumulated but are normally undergoing degradation or removal by erosion, and are generally marked by a more or less undulating or irregular surface, frequently with prominent occurrence of "hog-wallow" mounds and depressions. The soils of this group include those of the Madera, San Joaquin, Porterville, Oakley, and Fresno series.

Associated with these old valley-filling soils are less extensive areas of recent-alluvial soils. These occupy river flood plains and low recent-alluvial terraces in the vicinity of the large streams, and smooth gently sloping ribbon or fanlike areas upon the valley floor to which the material has been transported by small intermittent streams. Unlike the older valley-filling materials, the recent-alluvial soils have not been sensibly modified or weathered in place, are usually without compact subsoils or hardpan, except where occurring as overwash upon the older valley-filling materials, and are dominated in mineralogical character by the rocks from which they have been derived. They are usually of smooth topography, are, regionally, in process of accumulation rather than of erosion and removal, and the lower-lying areas are frequently subject to overflow. The soils of this group are represented by the Hanford, Foster, and Chino series.

PRINCIPAL SOIL SERIES OF THE DISTRICT

The essentially distinctive characteristics of the various series of soils represented in the survey are described briefly.

The Madera series consists of brown to somewhat reddish-brown soils underlain by compact subsoils, usually of heavier texture than

the surface soils, and by brown or yellowish hardpan. The hardpan material is firmly cemented and sufficiently impervious to retard subsoil drainage, and is frequently impenetrable to roots of vines and field crops. The cementing material appears to consist mainly of iron, but the hardpan sometimes contains thin seams or other local accumulations of lime. In the lighter-textured sandy types of the series developed in this survey, the hardpan is in many places deeply buried or absent, and the surface material may have been slightly modified by wind action. The variations in which hardpan is absent include some material now recognized as belonging to the Oakley series. The Madera series occupies slightly undulating areas, in which a hog-wallow configuration of moderate development may occur. Surface drainage is usually moderately well developed, but locally slightly depressed flats or areas of deficient drainage occur. Occurrence of alkali salts in injurious quantities is infrequent.

The San Joaquin soils, with which the Madera soils are associated, are composed of somewhat older and more highly oxidized and modified material of red to pronounced reddish-brown color. The soils normally occupy slightly more elevated positions, hog wallows are more common and more prominent, and the material is in places eroded or dissected by streams. The surface soils are low in organic matter, are readily puddled when wet, and bake and become very hard and compact when dry. They are somewhat less friable under cultivation than the Madera soils and are underlain by heavy, compact, red or reddish-brown subsoils and by red to brown, firmly cemented, noncalcareous hardpan, which effectually prevents percolation of water and penetration by roots. Surface drainage is generally well developed, except in local flats and hog-wallow basins, but some poorly drained areas occur, and subdrainage is restricted. The San Joaquin soils may be distinguished from the Madera soils by their slightly more elevated position and the more pronounced reddish color of the surface material.

The Porterville soils are typically of pronounced dark reddish-brown or deep chocolate-brown color. The surface soils, which are heavy in texture and of compact adobe structure, are underlain by heavy, compact and relatively impervious subsoils of brown, reddish-brown, or yellowish color, showing irregular seams and other concentrations of lime. A red indurated hardpan also occurs locally. As now recognized they include the soils classified in the earlier soil survey of the Fresno area under the Centerville series (7). The soils of the Porterville series are derived from old valley-filling deposits originating mainly from rocks of basic character or low quartz content, and occupy local to moderately extensive areas adjacent to certain of the first low foothill ridges along the eastern margin of the valley. The series is represented in this survey by a group of adobe soils.

The types included in the Oakley series have brown or light-brown soils and subsoils of sandy texture and open porous structure, but slightly if any heavier or more compact than the surface soils. They consist of wind-distributed materials, most of which in this locality have been derived from the sandy types of the Madera and the Fresno series. They are without marked concentration of lime or

cemented hardpan layers, except locally where occurring as shallow wind-laid deposits over hardpan soils of the Madera, San Joaquin, or Fresno series. The surface is gently undulating to hummocky, and both surface and internal drainage are generally adequate, except in localities where there is an accumulation of seepage water and a high water table.

The Fresno soils consist typically of light brownish-gray or gray soils, compact gray subsoils, and a gray or bluish-gray or brownish-gray calcareous hardpan. The sandier types have been somewhat modified by wind action, and in some of the included sandy material the hardpan occurs below the depth of 6 feet or is entirely absent. These areas are undulating in topography and are normally well drained, but the heavier-textured types occupy flat or but slightly uneven areas, in which both surface and internal drainage are poorly developed and injurious quantities of alkali salts commonly occur.

The Hanford series comprises types of brown to light-brown soils of friable, micaceous character, underlain by similar subsoils or by stratified stream-laid deposits, in which the strata have no regular sequence. The soils are of recent origin and are derived mainly from materials washed from granitic rocks. They are without characteristic heavy or compact subsoils or hardpan. Types of this series in many places occupy low-lying positions adjacent to stream channels and are subject to overflow.

The Foster series is closely related in origin, mode of formation, character of surface soils and subsoils, and manner of distribution to the Hanford series. The soils are distinguished from the Hanford soils by their prevailing darker grayish-brown or dull brown color. They usually occupy slightly lower areas than the Hanford soils, are perhaps more frequently overflowed, and neither surface drainage nor subdrainage is so well developed. Normally the content of organic matter is greater in the Foster soils. Accumulations of alkali salts resulting from imperfect drainage occur in many places.

The Chino soils are related to and associated with the Foster soils. They consist of dark-gray or very dark brownish-gray to black surface soils with subsoils of similar or somewhat lighter color. The material is prevailingly micaceous and obviously related, in origin and mode of accumulation, to that giving the Hanford and Foster soils. The soils of the Chino series occur under conditions of markedly restricted surface drainage and subdrainage, which have promoted an accumulation of organic matter and the development of a dark color. They frequently contain injurious accumulations of alkali, and there is a tendency toward concentration of lime in the subsoils, with noticeable compaction and slight cementation or the formation of calcareous nodules. In this respect the soils of this series exhibit evidence of modification in place since deposition, and approach in character the profile of the old valley-filling soils.

The characteristics of individual members of these series of soils, indicated upon the accompanying soil map and grouped in accordance with common textural and other physical features and observed relation to Phylloxera infestation, are discussed more in detail below.

THE SOIL TYPES AND THEIR RELATION TO PHYLLOXERA INFESTATION

MADERA AND SAN JOAQUIN SANDY LOAMS AND LOAMS

This group, Madera and San Joaquin sandy loams and loams, includes the sandy loam, fine sandy loam, loam, and clay loam types of the Madera and San Joaquin series, the sandy loam types predominating.

The included soils of the Madera series are distinctly brown, but locally become grayish brown along zones of contact with the soils of the Fresno series, and grade through reddish-brown variations into the redder soils of the San Joaquin series. When the soils are moist the brown color is usually more pronounced than when they are dry.

The included San Joaquin soils are predominantly of reddish-brown color when dry, but during the winter season and when viewed under moist field conditions they appear more pronouncedly red. Small ridges or knolls of the San Joaquin material surrounded and apparently partially buried beneath the younger Madera material, are usually distinctly red in contrast with the duller brown Madera soils.

In depth of material the surface soils are variable, but heavy or compact subsoils and hardpans commonly occur within 6 feet of the surface, and in the majority of cases within 1 to 4 feet. In some of the lighter-textured phases of the Madera sandy loam no well-developed hardpan or heavy subsoil is encountered. Such localities are exceptional and of local occurrence. The soil typically is low in organic matter, and neither surface soil nor subsoil is characteristically or consistently calcareous, though slight incrustations or accumulations of lime may occur. The hardpan is usually dense and impervious to water, though in the Madera soils, in which it is generally somewhat deeper and less dense than in the San Joaquin soils, it is sometimes slightly calcareous or less firmly cemented, and may have a tendency to soften under irrigation. Ordinarily, however, the hardpan effectively obstructs subdrainage and root development, and in planting to tree fruits, shattering or penetration of the hardpan by explosives, a practice frequently employed on the San Joaquin soils, is essential. The hardpan varies from but a few inches to several feet in thickness and is generally underlain by more friable unconsolidated materials.

The soils of this group occupy most of the central-northern and eastern parts of the vineyard district in Fresno County and the greater part of the more scattered vine-growing districts in Tulare County. In Fresno County the more extensive central-northern body extends north and west from Sanger to the San Joaquin River and about 6 miles west of Fresno. This area, however, is traversed or interrupted by ribbonlike streaks and small isolated bodies of irregular outline of the Madera and Oakley sands and of sandy loam soils of the Hanford series. The greater part of this soil area within the vineyard district consists of the Madera sandy loam, with small associated areas of the Madera loams, which give way to the San Joaquin soils about the margin of the vineyard area as outlined and in the region lying northwest of Fresno. In the vicinity of the foothill ridges upon the east a few small undifferentiated areas of

dark-colored old valley-filling soils of the Montezuma series are also included.

In the areas of these soils occupying the eastern part of the survey the sandy loam, loam, and clay loam types of the San Joaquin and Madera series, with local unimportant associated areas of other old valley-filling soils, are represented.

The soils of this group occupy smoothly undulating to nearly level lands, which are generally favorable to cultivation and the use of farming implements and to the practice of irrigation, though some rather elevated areas occur that are not readily reached by irrigation water, and numerous low ridges and mounds occur that are difficult to irrigate if not properly leveled. The Madera soils are somewhat more friable and more easily cultivated than those of the San Joaquin series, and are utilized for a wide range of fruits and farm products as well as for grapes. The San Joaquin soils are more restricted in utilization, and a large proportion of the area of these soils included within the survey and not planted with vines is utilized for dry-farmed grains and for pasture.

The physical character of the soils of this group is dominated by their compact subsoils, hardpan, restricted subdrainage, and a rather unfavorable or intractable structure. When wet the surface soils are sticky and tend to puddle and clod under cultivation. This condition is pronounced in the area of loam or heavier texture, and the sandy loam types, although prevailingly gritty because of the presence of quartz particles of the size of medium and coarse sand, have a structure usually associated with soils of heavier texture. Uncultivated areas lose moisture rapidly through evaporation, and the surface bakes and becomes very hard and checked or cracked. In cultivated vineyards or other field surfaces small to large clods ordinarily form, except under very thorough and intensive methods. This tendency to clod and bake is favored by a relatively large content of clay derived from the weathering of the feldspar, hornblende, and other minerals associated with the more resistant quartz fragments, and by the wet and boggy condition, following rains or irrigation, induced by arrested subdrainage.

In local low, flat areas, in which the hardpan occurs at shallow depth, the baked and checked or clodded condition of the surface soil is commonly most pronounced, though the subsoil in such places is frequently saturated at a depth of only 1 to 3 feet. Under these more or less adverse physical conditions, effective cultivation and irrigation are rather difficult, and careful and intelligent management in vineyard culture is imperative.

If cultivation or irrigation be too long delayed during dry periods, the soil becomes baked, and the roots of the vines become embedded in a hard mass of soil material, and often the tiny rootlets are injured from rupture by the fracture or checking of the material in which they have developed. On the other hand, in localities of inadequate drainage or excessive irrigation the subsoil becomes water-logged, and a condition of stagnated subdrainage and high water table results, with consequent development of shallow-rooted vines, which are readily affected by drought and unthrifty growth.

These conditions appear to render vines upon these soils particularly susceptible to phylloxera infestation, either through occurrence

of physical conditions in the soil favorable to the development and migration of the insect, or through the occurrence of localities of stunted or shallow-rooted vines with lack of stamina sufficient to withstand the ravages of the insect, which might be tolerated for a longer period in a deeper and more favorable soil.

The physical composition of typical samples of the soils of this group, with regard to the proportions of the mineral particles of the various sizes as indicated by mechanical analyses, by means of which the material is separated into the various grades, is shown in Table 1.

TABLE 1.—*Mechanical analyses of Madera and San Joaquin soils*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
MADERA SANDY LOAM								
572518	Soil	2.5	13.3	12.6	26.9	11.0	21.3	12.0
SAN JOAQUIN SANDY LOAM								
18718, 572524 [1]	Soil	6.7	16.2	8.8	18.3	12.0	28.6	9.1
18719	Subsoil	10.6	21.3	8.1	15.2	13.1	22.9	8.6
MADERA LOAM								
572521	Soil	0.9	5.1	6.3	21.7	16.2	31.8	18.0
SAN JOAQUIN CLAY LOAM								
572523, 572533 [1]	Soil	1.6	5.1	6.1	17.5	18.7	26.9	24.0
572534	Subsoil	.9	6.0	5.6	15.8	10.0	22.8	38.7

[1] The figures given are averages.

The relative proportions of the various grades of material determine the class or textural classification of the soil type. Material containing less than 20 per cent of silt and clay is designated as a sand, which may be a coarse, medium, or fine sand, depending upon the proportions of the sands of the various sizes (grades). Material containing from 20 to 50 per cent of silt and clay is classed as a sandy loam or fine sandy loam. Soil having a content of silt and clay exceeding 50 per cent, with a silt content of less than 50 per cent and a clay content of less than 20 per cent, is classed as a loam. When the material contains from 20 to 30 per cent of clay and less than 50 per cent of silt it is classed as a clay loam, but if the silt content exceeds 50 per cent it is classed as a silty clay loam, and if the clay content exceeds 30 per cent and the total silt and clay content exceeds 50 per cent it is classed as a clay.

From Table 1 it will be noted that the San Joaquin sandy loam contains a slightly higher proportion of silt and clay materials than the Madera sandy loam, whereas in the Madera loam and the San Joaquin clay loam the proportion of the finer materials is still fur-

ther increased, with corresponding decrease in the proportion of the medium and coarser sand particles.

In the surface soils of the sandy loam types the total content of the fine, medium, and coarse sands, including the particles lying between the 2 and 1 millimeter size and designated as fine gravel, is 55.3 and 50 per cent, respectively.

In the soils of this group in Fresno County a total of 88 borings and examinations of vines for the presence of phylloxera were made in suspected localities, and the presence of the insect was definitely established in 24 instances. In the majority of cases in which phylloxera was not identified the vines had died or become stunted, and unfavorable conditions of neglect in irrigation or cultivation or the occurrence of shallow hardpan or water-logged subsoils or other factors were observed, probably sufficient in themselves to have caused death or injury to the vines; however, the insect may at some time have infested the vines even if not positively identified at the time of this survey.

A comparison of the phylloxerated areas and the soil areas on the map indicates that an area of these soils lying immediately east of Fresno constitutes a locality of widespread infestation. Such infestation has probably radiated from one or more centers and has existed a comparatively long time. The area outlined constitutes the most extensive area of widespread infestation in Fresno County. A number of minute examinations of vines upon areas of the Madera and Oakley sands in the vicinity of and east and north of Las Palmas failed to establish any evidence of present or past infestation, though the insect was identified without difficulty upon vines growing in surrounding and adjacent areas of the Madera sandy loam and on the boundary between these types of soil. The infested area, as indicated upon the map, should not be interpreted as signifying that the insect itself was positively identified in all vineyards within the included district but that it was identified with consistent frequency, and that actual infestation exists or constitutes an imminent menace to the surviving vineyards in an area in which a large number of vineyards have succumbed and have been replanted upon phylloxera-resistant roots or have been replaced by other crops.

In addition to this area of widespread infestation, four areas of smaller extent on which occurred local infestation were identified upon the soils of this group in this locality. One of these occurs about 4 miles west of Fresno, two occur a short distance northeast and southeast, respectively, of Clovis, and another small area is located 1½ miles west of Sanger. Two other areas occur, partly upon the Madera sandy loam and partly upon more recent alluvial deposits referred to the Hanford series of soils, north and west of Clovis. These areas of local infestation upon the soils of this group are not extensive, but occur under soil conditions similar to those obtaining in the larger area of widespread infestation and constitute centers from which further infestation may readily extend.

Another area of widespread infestation occurs upon this group of soils in the vicinities of Dinuba and Cutler in Tulare County, and extends a short distance into Fresno County. Associated areas of the Madera, Oakley, and Hanford sands here also appear to be free

from infestation, and west of this area a narrow strip of these soils occurs in such a manner with regard to the phylloxerated area as to suggest that spread of infestation had been arrested by these soil materials.

The total area of phylloxera infestation, as indicated on the map, in the soils of this group in Fresno County is estimated by planimeter measurements to amount to 18,905 acres, and that in Tulare County to amount to 27,213 acres, a total of 46,118 acres, or 84 per cent of the total indicated area of phylloxera infestation in the two counties.

The general results of the observations seem to warrant the statement that no assurance can be given that infestation may not spread to the entire area of these soils, and that they must be considered as susceptible to general and widespread infestation, under which conditions the only assurance of safety from loss rests in planting upon phylloxera-resistant stock.

PORTERVILLE ADOBE SOILS

The Porterville adobe soils consist of dark-red to dark reddish-brown or pronounced chocolate-brown soils of heavy clay or clay loam texture, in places containing small quantities of waterworn pebbles, and of compact adobe structure. When wet the material is exceedingly adhesive. It requires careful management in cultural operations and heavy farming equipment, and if allowed to become puddled and baked, it forms an exceedingly hard compact surface deeply checked by intersecting cracks. Under favorable conditions of moisture and cultivation it can be maintained in a friable and well-granulated condition. The subsoil is brown or reddish brown and of heavy texture and compact structure. It is normally calcareous, and nodules, seams, and lenses, or grayish mottlings of irregular distribution caused by concentrations of lime, occur in places. Firmly indurated red hardpan was encountered in one or two instances, but this does not appear to be consistently developed and probably represents materials of the associated San Joaquin soils upon which the Porterville material has been deposited.

The Porterville adobe soils are confined to areas of small to moderate extent and irregular outline adjacent to some of the lower foothill ridges and outlying hills along the eastern margin of the survey. In Fresno County only a small proportion of these soils lie within the vine-growing districts. In Tulare County moderately extensive areas are devoted to viticulture in the vicinity of Yettem and southeast of Cutler, and in the vicinities of Redbanks and Exeter. Some of these soil areas are poorly defined and merge with associated soils of the San Joaquin and Madera series without distinct lines of demarcation.

These soils occupy smooth surfaces favorable to cultivation and have a high water-holding capacity. In some of the flatter areas both surface drainage and subdrainage are retarded. Deciduous tree fruits, as well as grapes, are grown to a small extent, and the soils are highly esteemed for the production of citrus fruits in the extensively developed citrus-producing areas in Tulare County. Phylloxera infestation in Fresno County on these soils was confirmed in

a local area occupying the valley slopes adjacent to Smith Mountain and lying about 5 miles east of Reedley. Other suspected localities occur in the southeastern part of T. 14 S., R. 23 E., but the occurence of the insect was not here confirmed, and the stunted and unthrifty appearance of the vines may be due entirely to other causes. The Smith Mountain area of infestation was later found to be coextensive with the large area of infestation upon soils of the Porterville, Madera, San Joaquin, and Hanford series in the Dinuba-Cutler-Yettem district, lying mainly in Tulare County. In the vicinity of Yettem this large area of general infestation is mainly upon heavy adobe soils of the Porterville series.

In Fresno County the phylloxerated districts on the Porterville adobe soils, as indicated on the map, cover an estimated area of 416 acres, and in Tulare County an estimated area of 6,445 acres, a total area in the two counties of 6,861 acres, or 12.5 per cent of the total indicated phylloxerated area in the two counties.

The adverse conditions of heavy texture and compact structure in relation to irrigation, subdrainage, and tendency of the soil to puddle, bake, and check, which prevail in the sandy loam and heavier soils of the Madera and San Joaquin series are accentuated in the heavy-textured soils of the Porterville series.

The results of mechanical analyses (Table 2) of typical samples of the Porterville clay adobe, which predominates, reveal a total silt and clay content in the surface soil of more than 75 per cent, which is usually indicative of an exceedingly heavy soil of compact structure. The total content of coarser materials of the first four grades in the surface soil is only 10 per cent, which is insufficient greatly to ameliorate the adverse physical condition associated with the high content of clay, which probably includes a large proportion of colloidal materials.

TABLE 2.—*Mechanical analyses of Porterville clay adobe*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
572554, 572558 [1]	Soil	0.1	1.0	1.6	7.5	12.6	35.9	41.2
572555, 572559 [1]	Subsoil	3.1	8.1	5.7	15.3	12.1	26.9	28.8

[1] The figures given are averages.

The physical characteristics of these soils, as compared with those of other soils in infested localities, and the observed widespread infestation in Tulare County, indicate that these soils must be regarded as favorable to widespread infestation, and therefore the precautions suggested in the preceding discussion of the soils of the Madera and San Joaquin series should be observed.

HANFORD AND FOSTER SANDY LOAMS

The group of Hanford and Foster sandy loams includes the sandy loam and fine sandy loam types of the Hanford and the Foster series of soils.

These soils are of light-brown to dark-brown color, the areas of darker soil representing Foster material in the lower and flatter situations adjacent to stream courses and subject to overflow or to poorly established drainage.

The soils of this group have a moderate to rather high content of organic matter, are only slightly sticky when wet, and are of open friable structure. Areas occurring near streams are frequently of somewhat lighter texture and more variable than those situated at greater distance from stream channels. The subsoil is for the most part similar to the surface soil. In some areas, however, the surface soils are underlain by strata of alluvial materials of variable texture, generally lighter in texture and more porous in structure than the surface soil, and they are without compact layers or hardpan. The soils occupy stream flood plains and low-lying stream-built terraces and alluvial fans, the materials of which have not been sensibly modified by weathering since deposition. The surface is generally smooth or but slightly uneven, and favorable to irrigation and cultivation, though sometimes interrupted by abandoned stream channels or by low terrace fronts. Some of the lower-lying areas are subject to a high water table or to overflow during flood periods, but the more elevated areas are well drained.

These soils are usually well adapted to intensive agriculture and are utilized for a wide variety of general farm, fruit, and truck crops.

They are of limited extent within the vineyard district in Fresno County, and only parts of the areas included are planted to vines. One of these areas extends along Big Dry Creek for a distance of several miles in the north-central part of the survey. In this locality the material consists mainly of recent-alluvial deposits of this stream, occurring in association with the Oakley and Madera sands and the Madera sandy loam. Much of the included material is not wholly typical of the Hanford soils, and some of it consists of overwash upon the heavier subsoils and hardpan of the Madera series. In the earlier soil surveys including this district this area of soils was not separated from the Madera and Oakley soils, and as outlined in the present survey parts probably conform as well or better to the Madera than to the Hanford series. There is, however, plainly an area of material here which consists of or has been modified by recent-alluvial deposits of friable, micaceous character and which is closely allied with the Hanford soils. The more important areas of this kind have in this survey been grouped with this series. The influence of recent alluvial deposits of Big Dry Creek extends below the limits of the area outlined and is locally apparent west of Fresno. Vines are planted upon a large proportion of this area of soils.

The other prominent locality in Fresno County occupied by these soils occurs along Kings River and its various branches and former channels east and southeast of Sanger. Parts of this area are of low elevation and deficient drainage and subject to overflow, and areas of high water table and accumulation of alkali salts occur. Grapes are grown to only a small extent upon the soils of the lower-lying river bottoms, but the more elevated areas occupying well-drained terraces in the vicinity of the Wah-to-ke vineyard in T. 14 S., R. 23 E., constitute an important vineyard center.

In Tulare County these soils are more extensively developed, the larger and more important area occupying the low, broad alluvial fan of the Kaweah River, and extending west and southwest from a point near Lemon Cove. Areas within the districts of vineyard plantings occur north of Cutler, in the vicinity of and northwest of Redbanks and in the vicinities of Exeter and Tulare. The areas in the vicinities of Cutler, Redbanks, and Exeter represent mainly the soils of the Hanford series. In those lying northwest of Redbanks and in the vicinity of Tulare the darker-colored and less well-drained materials of the Foster series, in which variable quantities of alkali salts occur in some places, predominate.

The soils of this group are easily cultivated and maintained in a favorable condition of tilth. They are not readily puddled when wet and do not bake or check upon subsequent exposure.

Results of mechanical analyses of samples of the Hanford sandy loam and Hanford fine sandy loam, representative of this group of soils, are given in Table 3.

TABLE 3.—*Mechanical analyses of Hanford soils*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
HANFORD SANDY LOAM								
572540	Soil	6.6	22.6	8.7	14.7	20.2	22.3	5.0
HANFORD FINE SANDY LOAM								
18701, 18702, 18703, 18723, 18725.[1]	Soil	2.3	5.8	2.0	22.2	22.3	38.0	6.8
18724, 18726 [1]	Subsoil	12.9	25.1	10.5	18.5	8.9	18.9	5.1

[1] The figures given are averages.

The low clay and moderate silt content indicate friable, easily cultivated soils. In the sandy loam type the total content of sandy material of the first four grades is high, being slightly in excess of 60 per cent, and the soil approaches in physical character the types of sand placed in a following group. In the fine sandy loam type the proportion of the fine and very fine sand and silt is increased, indicating a finer-textured soil of somewhat higher water-holding and moisture-retaining capacity.

In Fresno County detailed examinations were made in a number of localities of suspected infestation, and infestation by phylloxera was found to be frequent and quite widespread in an area extending through the northeastern part of T. 13 S., R. 20 E., and across the northwestern corner of the adjacent township upon the east. Infestation is not wholly confined to the soils of this group, however, but extends to adjoining areas of the Madera sandy loam. Another apparently isolated locality of infestation occurs upon the Hanford fine sandy loam in the southwestern part of T. 12 S., R. 21 E.

In Tulare County infestation apparently extends over the area of these soils lying north of Cutler and associated with the area of

widespread infestation in the sandy loam and loam types of the Madera and San Joaquin soils and the heavy-textured adobe types of the Porterville series.

No other infested areas were identified upon the soils of this group.

The total area of identified infestation in these soils as indicated on the map in Fresno County is estimated to cover 602 acres, and in Tulare County 1,280 acres, constituting a total in both counties of 1,882 acres, or 3.4 per cent of the total indicated phylloxerated areas.

In physical character the soils of this group are not such as would appear to be most favorable to widespread infestation, and the extent and position of the area of infestation along Big Dry Creek northwest of Clovis is such as to suggest that extension of infestation may have been aided by the distribution of the insect by the flood waters of this stream. The conclusion is reached that the soils of this group are less favorable to widespread infestation under normal conditions than are the soils of the preceding groups, but that areas of local infestation may and do occur. Planting upon nonresistant roots would be exceedingly hazardous within the vicinity of any of the centers of infestation.

MADERA AND OAKLEY SANDS AND FRESNO SAND AND SANDY LOAMS

The soils included within this group, Madera and Oakley sands and Fresno sand and sandy loams, consist of the sand types of the Madera and the Oakley series and the sand and sandy loam types of the Fresno series. With these are included also small local areas of fine sandy loam or loam of the Fresno series too small to be shown separately on the map.

The surface soils of the Madera and the Oakley sands consist of brown to light-brown sands of medium to rather coarse texture, low in organic matter, of open porous structure, and in most areas slightly loamy or sticky when moist. In the Madera sand the subsoil is normally slightly heavier and more compact than the surface soil and may consist of a compact sandy loam. The subsoil is typically underlain by hardpan, which, however, commonly appears at greater depth than in the Madera sandy loam. The areas of lighter texture have been modified somewhat by wind action, and where this action has been pronounced and the compact subsoil and hardpan of the Madera series is wanting or occurs below the depth of 6 feet, the soil represents undifferentiated material of the Oakley series.

The Fresno sand is in general appearance similar to the Madera sand, but has a slightly lighter grayish color, contains less organic matter, and is slightly more open and porous and less loamy when moist. It is typically underlain by a heavier or more compact subsoil and by gray to brownish-gray or bluish-gray calcareous hardpan within the depth of 6 feet. Where this heavier subsoil and hardpan material does not appear within this depth, the soil is recognized as representing material of the Oakley series.

The Fresno sandy loam consists of a light-grayish to light brownish-gray sandy loam, slightly more loamy and sticky when moist than the Fresno sand, low in content of organic matter, in places calcareous, and with a more compact or heavier subsoil and hardpan. The surface soil is, however, porous and friable, and

under cultivation forms a loose pulverulent mulch with few clods, and has a less pronounced tendency to bake and check than the Madera sandy loam. It is for this reason included, as indicated upon the soil map, with the lighter-textured and more friable porous soils.

The results of mechanical analyses of samples of the sand types of these series, and of the Fresno sandy loam, are given in Table 4.

TABLE 4.—*Mechanical analyses of light-textured Madera, Oakley, and Fresno soils*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
MADERA, OAKLEY, AND FRESNO SANDS								
4899, 4702, 4691, 3396, 4874, 4875, 4887, 328.[1]	Soil	*Per cent* 2.6	*Per cent* 12.6	*Per cent* 26.5	*Per cent* 27.2	*Per cent* 18.1	*Per cent* 8.6	*Per cent* 3.7
FRESNO SANDY LOAM								
572515	Soil	2.2	21.0	14.4	20.4	16.0	22.2	3.5

[1] The figures given are averages.

In the sands the combined silt and clay content amounts to 12.3 per cent, as compared with 33.3 and 37.7 per cent in the Madera and the San Joaquin sandy loams, respectively, and with 77.1 per cent in the Porterville clay adobe, and 27.3 and 44.8 per cent in the Hanford sandy loam and fine sandy loam, respectively.

The total of the first four grades of material in the sands is 68.9 per cent and in the Fresno sandy loam 58 per cent.

The soils of this group occupy extensive areas in the western and southern parts of the vineyard district in Fresno County. The more western area consists predominantly of the Fresno sandy loam and rather extensive associated areas of the Oakley and Fresno sands. The southern area, which includes nearly one-half of the vineyard district, consists predominantly of the Oakley and Fresno sands, and associated areas of the Fresno sandy loam. In addition a number of long, fingerlike areas and bodies of irregular outline are associated with the Madera sandy loam in the north-central and eastern parts of the survey; these consist mainly of the Madera sand.

These soils occupy areas which are generally nearly level to slightly undulating in case of the Fresno sandy loam, and undulating or gently rolling in case of the sand types. The areas of the Oakley and Fresno sands, in which modification by winds is most pronounced, exhibit a characteristic billowy or subdued dunelike topography. The elongated, narrow areas of the Oakley and Madera sands characteristically occur as slightly elevated ridges, but sometimes occupy practically the same level as associated Madera sandy loam areas, and do not differ from that type in topography or elevation. The surface of these soils is smooth and favorable to cultivation. The drainage is usually good, but the extensive area

of the Oakley and Fresno sands and Fresno sandy loam occupying the southern part of the district is traversed by occasional sloughs or shallow remnants of former stream channels or is interrupted by basinlike depressions, partly filled with water and occupied by tules or other swamp vegetation. Some of the included flatter areas of Fresno sandy loam are subject to a high water table and accumulation of alkali.

The soils are easily cultivated and maintained in a friable condition. In few places is there any pronounced tendency to bake and check, and these occur only in the heavier variations of the Fresno sandy loam. These soils are utilized for a wide range of fruits and other products and are extensively planted to vines of muscat and Sultanina (Thompson Seedless) varieties. A large number of localities were observed in which stunted or unthrifty vines occur and which in appearance simulate areas of phylloxera infestation. A total of 41 detailed examinations failed to reveal conclusive evidence of phylloxera infestation in any case. It is possible that the insect may have been present at some time in some of these places, but in nearly all cases indications of other causes, such as neglect of irrigation or cultivation, or local occurrence of high water table or alkali, or other factors were observed which were probably responsible for the unfavorable conditions. In a large number of instances the vines were found to be heavily infested with nematodes. In a number of cases a minute examination of vines growing upon the Oakley and Madera sands in close proximity to phylloxerated vines upon associated areas of the Madera sandy loam failed to reveal evidence of the insect. This was the case particularly in the vicinity of Las Palmas and in other localities in T. 13 S., R. 21 E., and in the northeastern part of T. 14 S., R. 19 E. In some of these cases the occurrence of the infested vines in relation to distribution of the soils strongly suggested that spread of infested areas upon the Madera sandy loam had been checked or prevented by intervening relatively narrow ridges or slightly elevated areas of the Oakley and Madera sands.

General results of observations appear to indicate that these soils are unfavorable to phylloxera infestation, and that planting can be extended with a wide margin of safety, though in the vicinity of infested areas upon other soils, planting upon resistant roots would probably be advisable.

HANFORD SANDS AND COARSE SANDY LOAM

The group of Hanford sands and coarse sandy loam includes gravelly sand, coarse sand, sand, fine sand, and coarse sandy loam types of the Hanford series. This is a group of loose, porous soils in which the sand and fine sand types predominate.

These types consist of light grayish-brown or buff-colored soils of friable structure, underlain by pervious subsoils of similar character or consisting of irregularly stratified recent-alluvial deposits in which those of coarse texture and of more porous character predominate. The coarse sand and coarse sandy loam are gritty and contain a large proportion of rather sharp and angular particles of quartz or granitic rocks. Of these two types the coarse sandy loam

is slightly more loamy. The fine sand has a smooth texture and generally contains numerous small scales or platelike particles of mica. Small quantities of waterworn pebbles may occur in the surface soil and subsoil in the vicinity of streams.

This group of soils is developed within the area surveyed in only a few localities, mainly in the vicinities of the San Joaquin, Kaweah, and Kings Rivers. The larger and more important of these areas within the vine-growing districts occupies a terrace east of the Kings River bottoms in T. 14 S., R. 23 E., and covers a portion of the Wah-to-ke vineyard. Another small area which is largely utilized for grape growing occupies a part of the Kaweah River bottoms above Lemon Cove, and a small area lies a short distance north of Cutler in the center of an extensive phylloxerated district. The other areas, the larger of which occur along Kings River east and northeast of Sanger, occupy parts of low, recent stream terraces and alluvial flood plains and are not to any great extent utilized for the production of grapes.

Results of mechanical analyses of samples of the Hanford gravelly sand and the Hanford sand are given in Table 5. In the Hanford sand, which is the more representative of the two, the total silt and clay content in the surface soil is less than 10 per cent, while the total of the first four grades in the surface soils is 71.3 per cent in the gravelly sand and 91.2 per cent in the sand.

TABLE 5.—*Mechanical analyses of Hanford gravelly sand and Hanford sand*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
HANFORD GRAVELLY SAND								
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
572505	Soil	10.2	29.9	13.9	17.3	11.1	14.4	3.1
572506	Subsoil	10.5	20.2	10.3	22.3	20.1	11.7	4.8
HANFORD SAND								
18697	Soil	14.1	52.5	13.1	11.2	1.8	5.4	1.5
18698	Subsoil	23.8	37.4	8.9	7.3	7.0	12.2	3.7

The surface is usually smooth and favorable to cultivation, and drainage is adequate, except for occasional overflows to which some of the lower-lying areas are subject. The soils are easily cultivated and readily maintained in a loose, friable condition. They are of rather low water-holding capacity but retain moisture fairly well under intensive cultivation.

In physical character the soils of this group most resemble the Oakley and Madera sands and the sand and sandy loam members of the Fresno series, but they lack the heavy subsoil or hardpan of the Madera and Fresno series. They do not become puddled when wet or bake or check when dry. But few localities were observed in which the appearance of the vines suggested phylloxera infestation, and in the instances in which detailed examinations were made no

evidence of the insect was found. The small area of these soils in the Cutler district in Tulare County is entirely surrounded by an area of widespread phylloxera infestation, but so far as observed the vines appear to have escaped the ravages of the insect.

The general conditions as observed in this survey would suggest that these soils are not favorable to infestation; however, because of their restricted occurrence, they are of small importance in the vine-growing industry.

FRESNO LOAMS

Fresno loams include the fine sandy loam, loam, and silt loam types of the Fresno series, the fine sandy loam predominating.

The Fresno fine sandy loam consists of a gray, light ash-colored, or light brownish-gray soil, and a gray or in places slightly yellowish-gray subsoil, typically slightly heavier or more compact than the surface soil, and carrying small concretions, nodules, and light-gray, brownish-gray, or bluish-gray calcareous hardpan. It is a widely recognized type of soil, locally known as "white ash land." The hardpan varies in depth of occurrence and thickness and may appear in a number of separate layers. Ordinarily it lies within 4 feet of the surface and in places only 1 or 2 feet of soil cover it.

The Fresno loam is similar in general features to the Fresno fine sandy loam but has a somewhat darker gray color, is of heavier texture, more sticky when wet, and more compact. It is not extensively developed within the vineyard districts. It commonly occupies relatively low, flat areas and shallow basins associated with the Fresno fine sandy loam.

The Fresno silt loam in essential characteristics of color, texture, and occurrence resembles the loam type of the series, but owing to higher silt content it has a slightly finer and less gritty texture.

As recognized in this survey, both the loam and the silt loam types may include small areas of darker-colored soils, with a dark-brown to dark-gray calcareous subsoil, recognized in the reconnaissance survey of the Middle San Joaquin Valley as types of the Merced series. These soils occur in the lower and flatter parts of the valley basin and are subject to stagnated drainage and in many places to overflow.

This group of soils is moderately extensive within the limits of this survey, but lies mainly outside the vineyard districts.

In Fresno County the larger areas occur in the northwestern part of the survey; and a number of small bodies of irregular outline are associated with the Oakley and Fresno sands and the Fresno sandy loam, especially in the vicinity of Fowler.

In Tulare County the group is somewhat more extensively developed, occurring as numerous areas of irregular outline in the flatter parts of the valley plains in the middle-western and southern sections of the survey.

The surface varies from gently undulating to flat, and has many long, narrow ridges and hummocks rising only a foot or two above the general level, interspersed with shallow basinlike depressions or flats. The lower-lying areas are poorly drained and subject to high water table and excessive accumulations of alkali salts. The soils in the shallow basins and other poorly drained areas are readily puddled and bake during hot, dry periods, although they do not

become as hard or check to as pronounced a degree as the types of corresponding texture of the Madera and San Joaquin series.

In Table 6 are given the results of mechanical analyses of samples of the Fresno fine sandy loam, the predominating type of this group. The soil is seen to consist mainly of fine sand, very fine sand, and silt, and has about 12 per cent of the medium sand and coarser grades. The clay content is somewhat lower, and the sands are finer than in the Madera and San Joaquin sandy loams.

TABLE 6—*Mechanical analyses of Fresno fine sandy loam*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
573502, 572504 [1]	Soil	*Per cent* 0.4	*Per cent* 5.3	*Per cent* 6.6	*Per cent* 23.9	*Per cent* 26.3	*Per cent* 30.2	*Per cent* 6.7

[1] The figures given are averages.

The more poorly drained areas of high alkali content are at present utilized mainly for pasture. Vine and tree fruits and hay and grain crops are grown upon the better-drained areas free from alkali, but the soils of this group are of minor importance in grape production. Areas of yellow or of stunted and unthrifty vines are of frequent occurrence in vineyards, but no evidence of phylloxera infestation was established, and neglect, occurrence of shallow hardpan, high water table, and accumulations of alkali probably contribute to the conditions observed. The physical character of the soils is somewhat adverse to intensive cultivation and maintenance of a favorable condition of tilth, and approaches that of the Madera and San Joaquin sandy loams and loams. These soils appear at present to support no areas of infestation, but it is probable that were the insect to be introduced through infested roots or by other means, infestation might occur. Because of their small extent and adverse conditions of drainage and alkali, however, the soils of this group will not constitute an important factor in the viticultural interests in these counties.

HANFORD, FOSTER, AND CHINO LOAMS

The group consisting of Hanford, Foster, and Chino loams includes the loam and, locally, small associated areas of the silt loam types of the Hanford, Foster, and Chino series. These types are intimately associated in occurrence and closely related in physical character, origin, mode of formation, distribution, topography, and drainage.

The surface soil of the Hanford loam is a brown to dull grayish-brown loam of micaceous character, friable structure, and moderate organic-matter content, underlain by similar materials or by strata of alluvial sediments of varying texture. The type is without hardpan or compact subsoil layers, except locally where it is developed as a veneer of recent-alluvial sediments over older, heavy or compact soil materials. It usually occupies areas of less well-developed drainage than do the sand and sandy loam types of the Hanford

and Foster series, and in places it contains injurious accumulations of alkali. It is of small extent in this survey.

The Foster loam differs from the Hanford loam mainly in its average darker grayish-brown or dull-brown color. In physical condition and character of soil profile it is essentially similar to the Hanford loam, and it passes into the Hanford soil without distinct boundaries. It is the predominating type in this group of soils.

The Chino loam, which is associated with the Foster loam, probably represents somewhat older and slightly modified deposits of material similar to that giving the latter type. The surface soil is typically dark brownish gray to black, and high in organic matter. The underlying material is somewhat compact and includes calcareous nodules or grayish zones or mottlings of accumulated lime. Both surface drainage and subdrainage are restricted.

The mechanical analyses of the Foster loam (Table 7) show the silt and clay content to be moderately high, the texture approaching a clay loam. There is, however, considerable variation in the texture of this and the associated types of soil, and some areas more closely resemble in physical character the sandy loam types of the Hanford and Foster series.

TABLE 7.—*Mechanical analyses of Foster loam*

Sample No.	Description	Fine gravel (2 to 1 mm.)	Coarse sand (1 to 0.5 mm.)	Medium sand (0.5 to 0.25 mm.)	Fine sand (0.25 to 0.1 mm.)	Very fine sand (0.1 to 0.05 mm.)	Silt (0.05 to 0.005 mm.)	Clay (0.005 to 0.0001 mm.)
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
18705	Soil	1.7	6.1	6.7	17.4	9.6	39.8	18.8
18706	Subsoil	.9	6.4	6.7	19.1	13.6	33.5	19.4

This group of soils is of small extent and restricted distribution in this survey. It occurs only in Tulare County, mainly as scattered areas associated with the Hanford and Foster sandy loams of the Kaweah River alluvial fan or delta and as areas lying between these soils and the flat alkali-impregnated areas of the Fresno loams. The surface is flat to very gently sloping or slightly uneven and is traversed by low ridges and shallow swales. Drainage is almost everywhere imperfectly developed, and, with the exception of small areas west of Tulare and Visalia, these soils are not at present utilized to any important extent for grape growing.

Although no areas of phylloxera infestation were identified in the soils of this group, the physical conditions of these soils appear to be somewhat more favorable to infestation and dissemination of the insect than are the Hanford and Foster sandy loams, and if once established it is probable that these soils would not prove immune.

SUMMARY OF RESULTS WITH RESPECT TO PREVAILING SOILS

The results of a study of the soils in this district as related to phylloxera infestation bear out general deductions from previous observations in other vine-growing centers of the State.

The larger proportion of instances of absolute confirmation of infestation occur upon the Madera sandy loam. This does not nec-

essarily indicate that this type of soil is more susceptible to infestation than other soils of similar physical characteristics, but it is due in part to the fact that it is an extensive type of soil widely utilized for vine growing. In the great majority of cases, however, both within the area studied in detail and in other localities investigated, infested vines occur upon soils identified as members of the Madera, San Joaquin, Porterville, or some other soil series derived from old valley-filling material, and characterized by heavy, compact subsoils or hardpan.

Infestation appears to be particularly frequent and pronounced in flat or depressed localities, where poorly developed drainage is aggravated by the occurrence of shallow, compact, and impervious subsoils and hardpan, giving rise to a condition of shallow-rooted vines and stagnated subsoil drainage. Where infestation occurs in deep, friable, recent-alluvial soils having porous subsoils, destruction of the vines is less rapid than in more shallow soils. Whether this is due directly to better drainage and to the physical character of the soils less favorable to the development and life processes of the insect, or whether the vines in the more friable and productive deeper soils are better able to resist injury caused by the insect, is not certain. It is probable that all these conditions are factors of importance.

Infestation is most frequent on soils of moderately heavy or heavy texture which become sticky when wet and bake and check when dry. It rarely occurs upon soils of sandy texture and of loose porous structure, which assume a dry, sandy, pulverulent condition in the field, even where in close proximity to areas of severe and long-standing infestation. The texture of the surface soils therefore appears to constitute a factor which may exert itself in a number of different ways. It is suggested that in soils of heavy texture and compact structure which bake and shrink and crack when dry, conditions are more favorable for prolification of the insect at certain stages of its development and for migration and dissemination by way of intersecting cracks and interstices in the soil mass and along the surfaces of the roots from which the material tends to withdraw slightly in shrinking. If forced to the highly heated surface of the sandy soils which do not bake and check, and which may be more uniformly in close contact with the roots than the soils of heavier texture when dry, the minute and delicate insect would probably not survive long under the hot, arid conditions to which most of the vineyards in the San Joaquin and other interior valleys are subjected. The heavy-textured soils which bake and check would probably afford more crevices and interstices for free movement of the insect and a better shaded and protected environment during migration.

Summarized results of observations in the vineyard district of Fresno and Tulare Counties, as related to prevailing soils, indicate:

That the sandy loams and soils of heavier texture of the Madera and San Joaquin series are favorable to general phylloxera infestation, and that areas of widespread and long-standing infestation occur.

That the adobe soils of the Porterville series, which are of heavy texture and of compact structure, are favorable to widespread in-